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(71) Applicant(s)
The City University

(Incorporated in the United Kingdom)

Northampton Square, LONDON, EC1V 0HB, United Kingdom

TFC Power Systems Limited

(Incorporated in the United Kingdom)

5 Broadlands Close, LONDON, N6 4AF, United Kingdom

(72) Inventor(s)
Ian Smith
Leonard Charles Constant

(74) Agent and/or Address for Service
Leonard Charles Constant
35 Upper Avenue, Istead Rise, NORTHFLEET, Kent, DA13 9DA, United Kingdom

(54) Orbital scroll expander for recovering power from flashing fluids

(57) An orbiting scroll machine is used as an expander of a volatile fluid to develop mechanical power. Fluid enters the machine through port 3 at high pressure as either a saturated or subcooled liquid or as a two-phase mixture with saturated liquid and vapour in thermal equilibrium. The expander acts as a prime mover and can be used for driving a gas compressor, an electric generator or any machine which would normally utilise a prime mover. The expander is particularly suited for applications where the required swept volume is in the order of 10 - 30 M.cu/Hr.

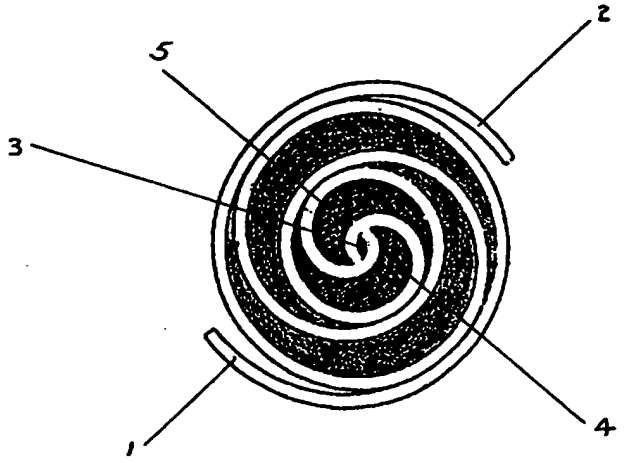

FIG. 1. GEOMETRICAL REPRESENTATION OF ORBITAL SCROLL EXPANDER

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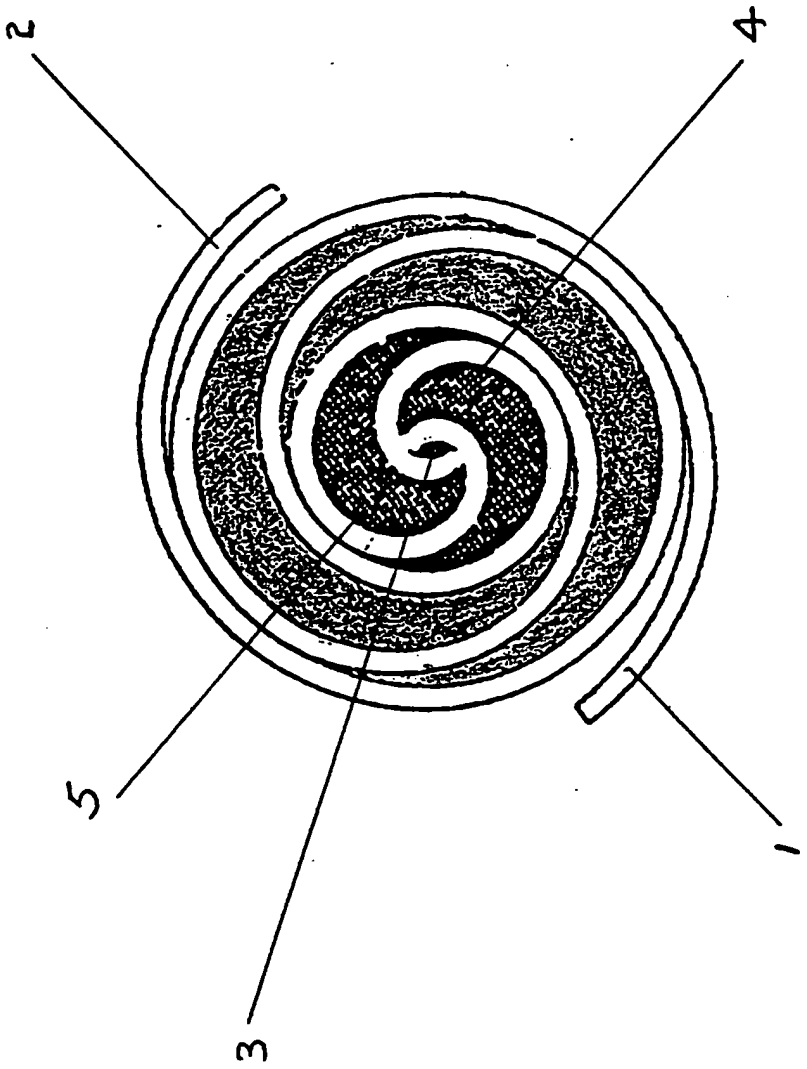
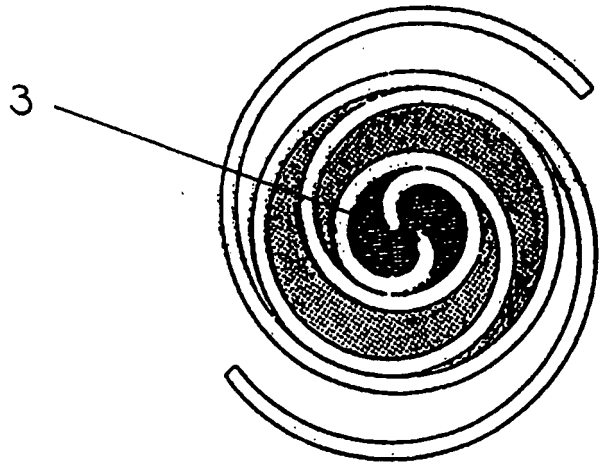


FIG. 1. GEOMETRICAL REPRESENTATION OF ORBITAL SCROLL EXPANDER.

STAGE 1.



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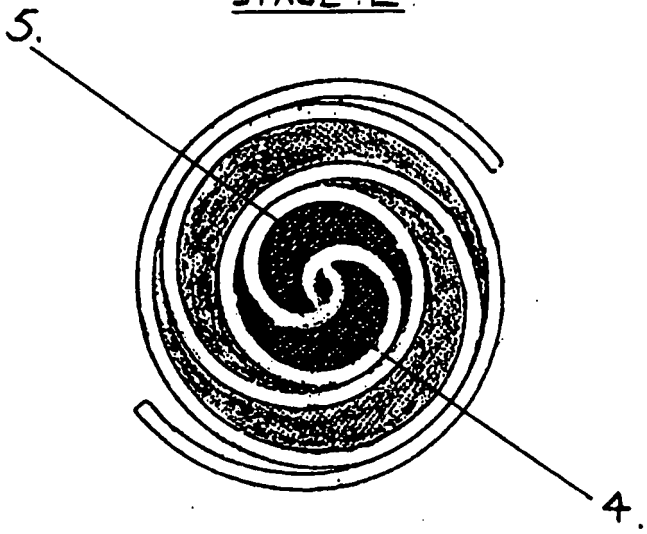

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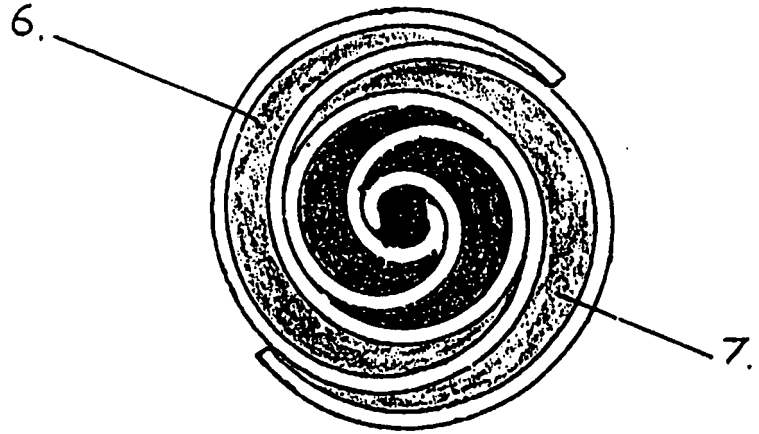

STAGE 4

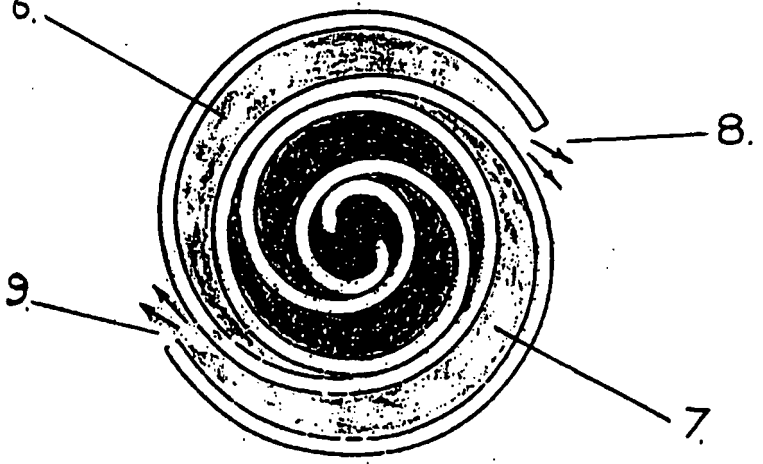

FIG. 2.

SEQUENCE OF OPERATION
FOR THE ORBITAL SCROLL EXPANDER.

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USE OF THE ORBITING SCROLL EXPANDER FOR THE RECOVERY OF POWER FROM FLASHING LIQUIDS.

Background.

The Orbiting Scroll mechanism was introduced into the refrigeration industry in the early 1980s as a gas compressor for use mainly on small air conditioning and heat pump applications. Larger sizes were subsequently developed although the fundamental geometry of the mating scrolls will probably limit the swept volume of the largest machine to about 30 M.cu/hr. in the forseeable future. The use of the Orbiting Scroll machine as a means of compressing gas is well known in the prior art and many units have been sold and are operating in the industrial, commercial and air conditioning markets throughout the World. It is noted for its low noise level, smooth operation and reliability, particularly in applications where substantial quantities of liquid refrigerant enter the machine. The capability of the scroll mechanism to accept entrained liquid with the gas being compressed is largely due to the semi- rolling action between the mating scrolls rather than the sliding action normally associated with piston, rotary and screw compressors. The low frictional contact between the two scroll discs allows scroll machines to operate without the need for oil injection into the scroll mechanism. It is this feature which makes the scroll machine particularly suited for the Trilateral Flash Cycle.

This application is concerned with the use of the orbiting scroll machine as an expander in the following;

i) The direct expansion of hot geothermal brines as describedby Sprankle in Aug 1973.

ii) As an organic fluid expander in the Trilateral Flash Cycle System described by I.K.Smith.

iii) As a throttle valve replacement in chemical process plant and vapour compression refrigeration and heat pump systems.

Configuration of an Orbital Scroll Expander.

Referring to Fig.1. two parallel flat discs 1. and 2. each having a raised spirally shaped strip on their flat surfaces are brought together to form an enclosed volume between them. The engagement is such that high pressure gas and liquid introduced between them through port 3.is trapped in the crescent shaped chambers 4. and 5. One of the discs is free to

orbit while the other remains stationary. The fluid is introduced into two diametrically opposite chambers simultaneously and expansion occurs evenly either side of the central driven shaft, thus ensuring a completely dynamically balanced assembly with very low loads on the driven shaft bearings. The expanding fluid is eventually discharged from the crescent shaped chambers when the orbiting scroll exposes the chambers to the low pressure outlet of the expander casing.There are no contacting seal grids to trap the fluid in the expansion chambers. Instead the machine is constructed with very small clearances between the two scroll discs and these are filled with the liquid components of the two phase mixture.

Expansion process in a Orbiting Scroll Expander.

The expansion process in an Orbiting Scroll Expander can be described in four stages with reference to Fig.2.

i) In the filling process stage 1. high pressure liquid or liquid and its associated vapour enter the machine at the centre through the inlet port. 3. and fill the available crescent shaped chambers.
In the case of dry gases this process occurs at approximately constant pressure. There is therefore no associated change in gas density during filling and neglecting leakage the mass flow induced is roughly proportional to the speed of the orbiting scroll.
In the case under consideration the process is more complex. The liquid or two phase mixture is more dense than compressed gases. The local acceleration associated with its passage through the inlet port therefore produces a more significant pressure drop, this in turn leads to flashing off of vapour from the mixture and hence changes the fluid density. The greater the speed of the orbiting scroll the larger the acceleration and thus the more the density changes. Accordingly the mass flow rate does not increase proportionally to the speed of the orbiting scroll and account must be taken of the pressure and volume changes associated with filling in the design of the machine to achieve a specified overall expansion ratio. Such changes cannot be inferred from dry gas expansion analysis.

ii) In the expansion process stage 2. further orbiting of the moving scroll leads to an increase in volume of the chambers 4. and 5 containing the trapped fluid. This expansion continues until the chambers containing the gas are exposed to the outlet of the expander casing.
In the case of dry gases the energy change associated with expansion is relatively large. the gain in kinetic energy of the gas due to its rotation in the chamber is then only a small percentage of the total. It may therefore be conveniently neglected and the analogy between expansion in the scroll chambers and the expansion process in a reciprocating engine cylinder is close.
In the case of two phase expansion, the decrease in energy per unit mass of fluid is much less. This is because the liquid component of the mixture, which can be in the order of 90% of the total mass, makes a negligible contribution to the work of expansion.The increase in kinetic energy of the fluid due to its rotation is therefore a much larger percentage of the total energy change. The pressure change associated with the expansion must include allowance for this or estimates of mass flow through the machine may be twice the value of those actually attainable.

iii) The optimum expansion process stage 3. is reached immediately prior to the chambers 6. and 7. being exposed to the expander outlet gallery due to further orbiting of the moving scroll.

iv) Completion of the expansion process stage 4. occurs when chambers 6. and 7. are exposed to the outle galleryat points 8. and 9. The liquid- vapour

mixture passes into the outlet gallery of the expander and through the outlet connection. Ideally the pressure in the outlet gallery should be substantially equal to that in the scroll chambers at the instant that discharge begins. If this is not achieved then a loss in efficiency can occur. If the pressure in the scroll chambers is greater than the outlet pressure when the chambers are exposed then wasteful flash expansion will take place during discharge. If the pressure in the scroll chambers is lower than the outlet pressure, fluid will flow back into the expansion chambers at the point of exposure, resulting in inefficiency. Further orbiting of the scroll expels the residual fluid displaced by the engaging scrolls at points 8. and 9. Ideally the exit port from the casing of the expander should be directed vertically downwards to prevent the accumulation of liquid within the body of the machine.

An important feature of the two phase expansion process is that the overall expansion ratio must be determined by external conditions such as the evaporation and condensation processes in vapour compression systems. It is therefore an essential feature of this invention that the expansion process begins by passing the fluid through a variable control valve which may be opened or closed in response to control signals in order to maintain the inbuilt volume ratio required for total expansion.

The main feature of the Orbiting Scroll Expander which makes it ideally suited for small two phase applications is that it is not necessary to inject oil into the scroll chambers for lubrication or sealing of the engaging scroll discs. A small amount of oil migrates into the expansion chambers from the bearings but this is less than 3% which is insufficient to affect the vapour pressure of the fluid and hence the expansion efficiency. Liquid in the expansion chambers fills the the small clearances and ensures that leakage is minimal.

CLAIMS

1. The use of an Orbiting Scroll Expander for the direct expansion of hot geothermal brines

2. The use of an Orbiting Scroll Expander as the prime mover in the Trilateral Flash Cycle system.

3. The use of an Orbiting Scroll Expander as a throttle valve replacement in chemical process plant, air conditioning, refrigeration and heat pump systems.

4. The use of an Orbiting Scroll Expander as a throttle valve replacement whereby it drives a compressor in a sealed unit to augment the performance of existing refrigeration, air conditioning or heat pump systems.

5. The use of an Orbiting Scroll Expander in an oil free mode.

6. The use of an Orbiting Scroll Expander with no oil control seals between rotors and bearings.

7. The operation of an Orbiting Scroll Expander with large quantities of liquid, compatible with the TFC system, passing through the machine.

8. Use of an Orbiting Scroll Expander over the capacity range 10-30 M cu/hr. This size cannot be covered by the larger Twin and Single Screw Expanders.

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Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9524384.6
Relevant Technical Fields (i) UK Cl (Ed.O) F1F (FD, FEX, FEQ, FAA, FAX) (ii) Int Cl (Ed.6) F01C 1/00, 1/02, 1/04	Search Examiner C J DUFF Date of completion of Search 9 JANUARY 1996
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1, 2, 7, 8

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	P:	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	E:	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	&:	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
Y	GB 2282852 A	(CITY UNIVERSITY) whole document	1, 2, 7, 8
Y	GB 1447607	(LITTLE) see page 1, lines 11-29	1, 2, 7, 8
Y	US 3751673	(SPRANKLE) See Figure 1; column 3, lines 6-16	1, 7, 8

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).